



On October 10, 1996, President Clinton and Vice President Gore announced their commitment to the Next Generation Internet (NGI) Initiative, based upon strong research and development programs across Federal agencies. The Large Scale Networking Working Group of the Computing, Information, and Communications R&D Subcommittee has drafted a paper that outlines the concepts and goals of the NGI Initiative as part of the process for building the strongest possible program among academia, industry, and the government. This draft is being released for public comments and discussion. Your feedback is encouraged. Comments received by 15 May 1997 will be used in preparing a final version of the document shortly thereafter.

At the end of each section of the draft paper is a provision for comments to be sent via email to the ngi@hpcc.gov. Clicking on the envelope at the end of the section will bring up an email window in which you may type your comments. By clicking on the "Send" button in the email window, your comments will be automatically sent. If you wish, comments and suggestions can also be sent by FAX to 703-306-4727. or can be sent at any time to ngi@hpcc.gov.

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Table Of Contents

1. [Introduction](#)
 - [The NGI Vision](#)
2. **Goals, Strategies and Metrics**
 - [Introduction](#)
 - Guide to the Remainder of this Paper
 - [Goal 1: High-performance Network Fabric](#)
 - Strategy for Goal 1
 - Metrics for Goal 1
 - [Goal 2: Advanced Network Service Technologies](#)
 - Strategy for Goal 2
 - Metrics for Goal 2
 - [Goal 3: Demonstration of New Applications](#)
 - Strategy for Goal 3
 - Metrics for Goal 3
 - [Five-year Roadmap](#)
 - [Transition Strategies](#)
3. [Expected Deliverables](#)
4. [Expected Benefits](#)
5. [Management](#)
6. **Action Plan**
 - [Goal 1: High-performance Connectivity](#)
 - High-performance (hundreds 100x) Connectivity
 - High-performance (10s 1000x) Connectivity

- **Goal 2: Advanced Network Service Technologies**

- Overall Strategy
- QoS Action Plan
- Protocol Action Plan
- End-System Considerations
- Operating Systems Action Plan
- Collaborative and Distributive Environment Action Plan
- Overall Systems Considerations
- Network Management Action Plan
- Engineering Action Plan
- Security Action Plan
- Scalability Action Plan

- **Goal 3: Demonstrate New Applications**

- Action Plan
- Selection Criterion
- Sample Applications
- Characteristics and Requirements of Demonstration Applications
- Deliverables

Appendix 1. Collected Requirements of Demonstration Applications

Appendix 2. Agency roles in the NGI

- **Defense Advanced Research Projects Agency**
- **Department of Energy**
- **National Aeronautics and Space Administration**
- **National Institute of Standards and Technology**
- **National Science Foundation**



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1. Introduction

The Internet is one of the most important advances in human communications since the printing press. Every day this rapidly growing global network touches the lives of millions of Americans. Students log into the Library of Congress or take virtual field trips to the Mayan ruins. Entrepreneurs get the information they need to start new businesses and sell their products in overseas markets. Researchers access supercomputers and experimental facilities and maintain world-wide research collaborations with their colleagues. Caregivers for people with Alzheimer's Disease participate in an "extended family" on the Cleveland FreeNet. Citizens keep tabs on the voting records and accomplishments of their elected representatives. During the 1996 election night, a Web server maintained by Cable News Network received over five million visits per hour -- a total of over fifty million visits.

Today's Internet is an outgrowth of decades of Federal investment in research networks such as the Defense Department's ARPANET, the National Science Foundation's NSFnet, the Department of Energy's ESnet, the National Aeronautics and Space Administration's NASA Science Internet, and NSF-initiated regional networks which have been applied in successive evolutionary multi-agency programs that build on the successes of the previous programs. This small amount of Federal seed money stimulated much greater investment by industry and academia and helped create a large and rapidly growing market. The NGI is the next, but perhaps not the last, logical step in the cycle of evolving networking infrastructure and technologies necessary to support U.S. research and industry.

Today's Internet suffers from its own success, however. Technology designed for a network of thousands is laboring to serve a network of millions. Industry observer and Ethernet inventor Robert Metcalfe predicts the crash of the Internet. Many disagree with Metcalfe, pointing to the Internet's ability to continue functioning under overload -- but everyone recognizes the crisis.

Fortunately, scientists and engineers believe that new technology, protocols, and standards can be developed to meet tomorrow's demands. These advances will start to put us on track to a next generation Internet offering reliable, affordable, secure information delivery at rates thousands of times faster than today. Achieving this goal will require several years of generic, pre-competitive research and testing. It is appropriate that the Federal government promote and participate in this research because critical Federal missions require a next generation Internet for their success and because much of the needed research is too long-term or high-risk for the private sector to fund. As in the Internet development to date, success will depend on effective partnerships among universities, the private sector, and the Federal research community.



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The NGI Vision

In the 21st Century, the Internet will provide a powerful and versatile environment for business, education, culture, and entertainment. Sight, sound, and even touch will be integrated through powerful computers, displays, and networks. People will use this environment to shop, bank, study, entertain, work, and visit with each other. Whether at home, at the office, or on travel, the environment will be the same. Privacy, security, and reliability will be built in. The customer will be able to choose among different levels of service with varying prices. Benefits of this environment will include a more agile economy, a greater choice of places to live or work, easy access to life-long learning, and better opportunity to participate in the community, the nation, and the world.

The Next Generation Internet (NGI) initiative, together with all the investment sectors shown in Figure 1, will create a foundation for the more powerful and versatile networks of the 21st century. It will foster partnerships among academia, industry and government that will keep the U.S. at the cutting-edge of information and communications technologies. It will accelerate the introduction of new networking services for our homes, schools, and businesses. It is important to realize, however, that this initiative is possible only because of the very strong agency programs that are currently underway. The Large Scale Networking R&D crosscut for FY 1998, for example, is \$288.3M, which includes the \$100M for NGI. This document focuses directly on the concepts and goals of the \$100M NGI initiative.

NGI: "The Programs"

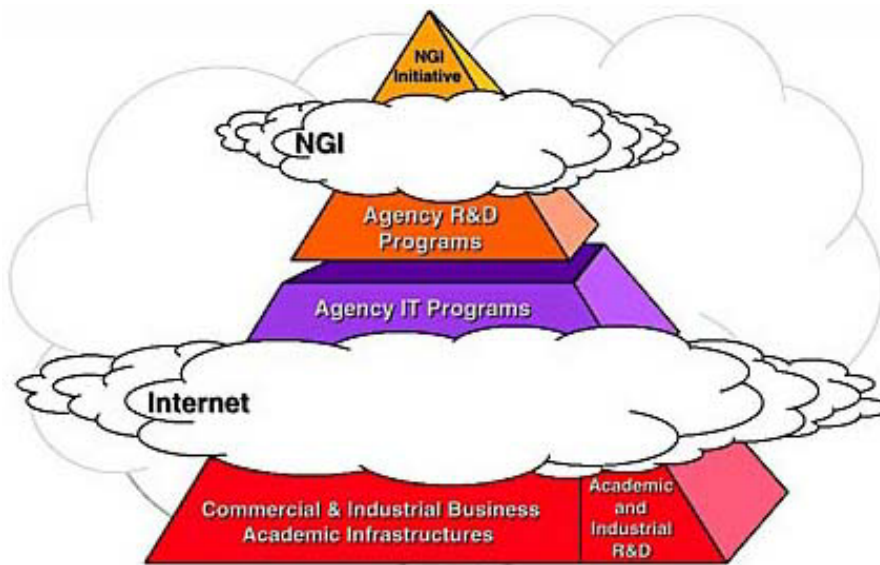


Figure 1.

The most important part of a network is what people do with it -- their applications. But applications require adequate network services and infrastructure. The NGI initiative will conduct research to advance all three areas together: applications, services, and infrastructure.

As one of its goals, the NGI initiative will enable advanced science, health, education and environmental network applications. These applications will be selected from the participating agencies and from other government missions and will be carried out in partnerships between the initiative and other programs. The role of applications in the initiative will be to demonstrate the value of advanced networking and to test advanced networking services and technology.

As a second goal the initiative will develop and test new network services and technologies. These will include advances such as transaction security, ease-of-use, quality of service, and tools for network monitoring, management, and accounting. Many of these new services and technologies already exist as individual components, but substantial system integration and testing at sufficient scale will be required for them to provide seamless support for advanced applications.

As a third goal, therefore, the initiative will develop prototype high-performance network infrastructure, or testbed, to provide system-scale testing of advanced services and technologies and to support testing of advanced applications that enable new paradigms of use. This testbed will emphasize end-to-end performance to the user. Therefore significant upgrades of local infrastructure within participating sites will be needed as well as high-performance links among sites.

Advanced services and technology will be key to the success of this testbed and its overall utility in delivering applications. As an analogy, consider the country's system of highways and streets. The ribbons of concrete and asphalt, the raw capacity of the system, are like the fiber-optics, copper, and computers of the network. The intelligent features of the highway system -- traffic lights, HOV lanes, lane markers, street signs -- are like the services and technology of the network. The utility of both highways and networks depends on the proper mix of size, technology, and services. The system must be engineered as a whole: interstate highways dumping directly onto narrow streets are like high-bandwidth network links dumping into slow local-area networks.

The initiative will be built on partnerships: partnerships between researchers developing advanced networking technologies and researchers using those technologies to develop advanced applications; and partnerships between federally-funded network testbeds and commercial network service and equipment providers who participate in these testbeds to test concepts for the future commercial Internet. In addition, it will focus and stimulate other Federal programs, from research and development to shaping future IT procurement visions.

On October 10, 1996, in Knoxville, TN, the President and Vice President announced their "commitment to a new \$100 million initiative, for the first year, to improve and expand the Internet.... " This NGI initiative carries out that commitment.

The initiative is planned to last five years. The Administration has made an initial three-year \$300 million funding commitment of \$100 million per year, and will seek bipartisan Congressional support in its budget submissions. Built on the base of current Federally-funded research and development, the initiative will also call on substantial matching funds from private sector partners, as well as seek commitments from major applications developers.

The potential economic benefits of this initiative are enormous. Because the Internet originated in the United States, American companies have a substantial lead in a variety of communications and information markets. The explosion of the Internet has generated economic growth, high-wage jobs, and a dramatic increase in the number of high-tech start-up companies. The Next Generation Internet initiative will strengthen America's technological leadership and create new jobs and market opportunities.



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2. Goals, Strategies and Metrics

including roadmap and transition strategies

2.1 Introduction

The U.S. Government created the ARPANET as a research network over 25 years ago to prototype the technology and community needed for a new type of network. In this new technology and community-- which became today's Internet-- sites are interconnected openly with other sites through a flexible, richly connected fabric that allows users to exchange data and information freely and easily. Through the development of the Internet, the U.S. Government has led the world into a new way of communicating.

Now we are on the threshold of a next generation Internet (NGI), one that has the potential again to create a new type of interconnected community. This NGI community will be able to exchange information in far richer ways and with far less delay and risk than using today's Internet. To reach that vision, there are three goals for this NGI initiative, each with a strategic approach and each with metrics of success. The three goals are:

1. High-performance Network Fabric,
2. Advanced Network Service Technologies, and
3. Revolutionary Applications.

The nature of research implies that success in reaching goals is never guaranteed. The NGI commitment to the definition and use of metrics will, however, assure that NGI resources are targeted at clear objectives and will signal when those objectives are achieved.

Guide to the Remainder of this Paper

Sections 2.2 through 2.4 describe the three specific goals of the NGI Initiative, summarize the strategies for achieving each goal, and define the metrics of success. These sections also summarize specific transition strategies for each goal. The action plans in Section 6 detail the goals and how the initiative will achieve them.

Section 2.5 provides a summary, five-year annual roadmap of the initiative. Sections 3 and 4 detail the expected deliverables and benefits respectively.

Section 2.6 summarizes the strategies for transferring results to the broader public and private Internet community including the commercial sector. The management interrelationships and dependencies are contained in Section 5.



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2.2. Goal 1: High-performance Network Fabric

Develop the next generation network fabric and connect universities and Federal research institutions at rates that are 100 to 1000 times faster than today's Internet.

The networks developed under the NGI Initiative will connect at least 100 NGI sites -- universities, Federal research institutions, and other research partners -- at speeds 100 times faster than today's Internet. Although changing over time, we will assume that the average speed in 1997 is 1.45 Mbps. The NGI networks will connect on the order of 10 NGI sites at speeds 1,000 times faster than the current Internet.

This goal addresses end-to-end connectivity (to the workstation) at speeds from 100+ million bits per second (Mbps) up to 1+ billion bits per seconds (Gbps). Although some networks have already achieved OC-12 speeds (622 Mbps) on their backbone links and some experimental links are running at 1+ Gbps, end-to-end usable connectivity is typically limited to less than 10 Mbps because of bottlenecks or incompatibilities in switches, routers, local area networks, and workstations. Goal 1 addresses these shortcomings by developments and demonstrations involving two sub-goals.

- **Subgoal 1.1 (high-performance connectivity)** Develop a wide-area demonstration network fabric that will function as a distributed laboratory, delivering 100X current Internet performance end-to-end (typically greater than 100+ Mbps end-to-end) to 100+ interconnected NGI sites demonstrating highly important applications. This demonstration network fabric must be large enough to provide full-system, proof-of-concept tests of hardware, software, and protocols required in the commercial next generation Internet.
- **Subgoal 1.2 (next generation network technologies and ultra-high-performance connectivity)** Develop the ultra-high speed switching and transmission technologies and demonstrate end-to-end network connectivity at 1000X current Internet performance end-to-end (typically greater than 1+ Gbps end-to-end and many Gbps in backbone circuits. Because of its greater cost and engineering difficulty, this subgoal will be achieved in smaller wide-area demonstration networks involving about ten NGI sites and applications. These applications must be drivers of the properties of very-high-speed networks; that is, they must stress the network hardware, software, and protocols to determine the true benefits, characteristics, and limitations of the system and its components under the heavy loading needed for a commercial NGI.

Strategy for Goal 1

The primary strategy for achieving Goal 1 is for Federal agencies to build high-performance, collaborative networks in partnership with the telecommunications and Internet provider industries and top Federal research institutions. These network testbeds must include enough sites to test whether proposed technologies scale to large networks and to support the demonstration of widely distributed applications. This is an example of Metcalfe's law that the value of the network scales as the square of the number of sites.

The Subgoal 1.1 networks would interconnect most of the top research universities and Federal research institutions in the country through a fabric delivering 100+ Mbps end-to-end in an interoperable mesh richly interconnecting the vBNS, ESnet, NREN, DREN, and other appropriate networks. The Subgoal 1.2 network

would seek to demonstrate a few high-end applications at a small subset of the above sites with much higher end-to-end performance.

To accomplish the technology envisioned, this initiative will fund universities, industry R&D and Federal research institutions to explore innovative ideas of switching and transmission.

The NSF Very High Bandwidth Network Service (vBNS), the Energy Sciences Network (ESnet), and the NASA Research and Education Network (NREN) are examples of the network partnership arrangements strategy for achieving Subgoal 1.1. These arrangements have provisions allowing the agencies and the providers to work together to build prototype networks with various combinations of cost discounting, flexible service provisioning, and pre-competitive technology partnering.

The Subgoal 1.1 network fabric would include the vBNS augmented by the NSF Connections program, and opportunities that may emerge from the Internet2 project. NSF's vBNS/Connections is now interconnecting many U.S. research universities with a next generation fabric using leading-edge network technologies as building blocks. Also included in Subgoal 1.1 will be ESnet and NREN. Also included in the Subgoal 1.1 will be ESnet and NREN. The Subgoal 1.1 NGI initiative will enable many more universities and Federal research institutions to connect to the evolving next generation Internet infrastructure at a faster pace than can be without NGI funding. Internet2 is a community-based project of about 100 universities working to dramatically improve their campus infrastructure and Internet connectivity. The NGI initiative will work directly with the Internet2 project to facilitate tying their high-performance campus backbones into the NGI infrastructure.

The Subgoal 1.2 network -- the ultra-high-performance part of NGI -- could be a separate network fabric with links to the Subgoal 1.1 network fabric, but may also be implemented on some of the same infrastructure as goal 1.1 and 2. This network will have Gb/s end-to-end connectivity, advanced network management, and negotiated quality of service functions

The Subgoal 1.1 network must be highly reliable except under carefully planned and implemented experiments because it must support at least 100 institutions developing software and applications. The Subgoal 1.2 network fabric would involve very early implementations of ultra-high-performance technologies and should be expected to break periodically under normal daily operations.

The Goal 1 strategy of having Federal agencies take the lead in building the networks in partnership with telecommunications companies, network service providers, and research institutions is modeled after the way the existing Internet was developed. This approach will ensure that successful network technologies developed under this program are immediately available commercially and will be widely marketed and fairly priced. The immediate availability will come about because the networks will be provided by commercial partners under contracts and cooperative arrangements. The partners will be able to market commercial versions of these next generation technologies and services as soon as the technologies and services are commercially viable. The partners, working through the existing Internet organizations such as the IETF and ATM Forum, will ensure that the lessons learned are widely disseminated and freely available to all.

Metrics for Goal 1

The primary metrics of success for Goal 1 are the following:

- **Number of institutions connected.** The first part of Goal 1 is to connect at least one hundred NGI sites to the Subgoal 1.1 network fabric and at least 10 sites to the Subgoal 1.2 network fabric. Therefore, a primary metric is the number of sites connected. The list and status of NGI sites will be continually updated and available on the public web page maintained by NGI (see Management section).
- **End-to-end performance.** The second part of Goal 1 is to achieve 100+ Mbps end-to-end performance over the Subgoal 1.1 network fabric and 1+ Gbps end-to-end performance over the Subgoal 1.2 network fabric. "End-to-end" means between application operating within the NGI testbed network. NGI will carry out standard end-to-end performance measurements between user systems. The NGI public web page will report the results of these measurements for each participating site, and the experimenters will analyze and report the results in technical conferences and journals.



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2.3 Goal 2: Advanced Network Service Technologies

Promote experimentation with the next generation of networking technologies.

The NGI initiative should develop and demonstrate all the advanced network service technologies needed to support next generation applications. For NGI to be successful, it is not sufficient merely to deploy a testbed that can move bits at 100 Mbps to 1 Gbps because an Internet is not merely the movement of bits, and a next generation Internet is not merely faster movement of bits.

The NGI applications will require a rich collection of advanced network services. For example, high-quality team collaboration and videoconferencing support requires several types of network services unavailable on the Internet today. These services must be richer in features, higher in performance, and deliverable at reasonable cost. Achieving all three of these apparently conflicting subgoals simultaneously will drive NGI technology. The NGI Initiative will fail if it deploys faster networks without also developing and demonstrating the richer, more flexible, and affordable network service technologies needed by next generation applications.

The main areas of network services and corresponding protocols that need to be developed and demonstrated are the following:

- Quality of service (QoS)
- Security and robustness
- Network management, including the allocation and sharing of bandwidth
- Systems engineering and operations, including definitions and tools for service architectures, metrics, measurement, statistics, and analysis
- New or modified protocols for routing, switching, multicast, reliable transport, security, and mobility
- Computer operating systems, including new requirements generated by advanced computer architectures
- Collaborative and distributed application environments

Strategy for Goal 2

The primary strategy for achieving Goal 2 is to fund university, Federal and industry R&D organizations to develop and deploy the needed services, protocols, and functionality required by the network infrastructure and applications. This will be done in an open technology transfer environment within the framework of collaboration as exemplified by the IETF, ATM Forum, Educom, etc.

This strategy, which determined the success of the original Internet is one where good ideas are funded and open versions of products and services are made available to the community. Organizations use the openly published software and specifications to provide both "freeware" and commercial products. This strategy provides effective and very efficient development, selection, and distribution mechanisms for successful technologies.

Hugely successful companies such as Sun Microsystems, Cisco Systems, and Fore Systems are the by-products of this strategy, and so are widely used freeware products such as the Mosaic and Eudora. This strategy has resulted -- and will again result -- in speedy transition of successful technologies into the marketplace. These

technologies will appear as competitively priced and aggressively marketed products that enable U.S. companies to develop and promote new products for new international markets.

Metrics for Goal 2

The primary metrics of success for Goal 2 are the following:

- **Quality of service.** The qualities of service (QoS) actually achieved end-to-end over the network are measurable quantities. Such QoS metrics as end-to-end latency, packet loss, and packet arrival jitter, as well as guaranteed min-max bandwidth allocation, are used in defining the technical specifications for the service needs of the next generation of applications. Developers will specify and continuously measure the most important QoS metrics and report them for all applications, delivered under Goal 2.
- **Security and robustness.** Measures of security and robustness will be developed as part of Goal 2. These measures will quantify the security and robustness deficiencies of today's Internet in a way that improvements may be planned and measured. The goal in this area is to implement the type of network that individuals and businesses can trust to carry their private and company-confidential information, safe from disclosure or alteration, as well as providing for authenticated transactions and access.
- **Other subgoal measures.** The NGI management team will associate quantitative metrics with each of the other important network services that are adopted as primary subgoals of Goal 2. The team will use each of these subgoal metrics actively to plan and validate the technologies developed under Goal 2.
- **Extent to which technologies are adopted by commercial Internet suppliers.** A primary part of this goal is the transition of successful technologies quickly to the commercial sector. The strategy of working openly-"Internet style"-will achieve this in the quickest possible way. NGI will maintain reports and measurements of NGI-developed technologies that have been incorporated into commercially available products. This may be done by requiring no-cost licenses for the use of NGI-developed technologies or by other means identified by the teams described in Section 5. Management.



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2.4 Goal 3: Revolutionary Applications

Demonstrate new applications that meet important national goals and missions.

A fundamental objective for the NGI is to demonstrate a wide variety of nationally important applications that cannot be achieved over today's Internet. Ideally, these applications will include Federal agency mission applications, university and other public sector application, and private sector applications. These applications will improve U.S. competitiveness in existing business areas, and they will demonstrate the potential for entirely new business areas based on commercializing the technologies developed within this initiative.

Potential application areas for the NGI include the following:

- Health care: Telemedicine, emergency medical response team support
- Education: Distance education, digital libraries
- Scientific research: Energy, earth systems, climate, biomedical research
- National security: High performance global communications, advanced information dissemination
- Environment: Monitoring, prediction, warning, response
- Government: Delivery of government services and information to citizens and businesses
- Emergencies: Disaster response, crisis management
- Design and manufacture: Manufacturing engineering

Many of these areas are of particular Federal interest since they represent Federal mission-critical applications that require advanced networking services and capabilities. The Federal government's information technology services and federally supported communities have networking requirements that cannot be met with today's Internet technology. Higher speed networks with more advanced services and functionality will enable a new generation of applications that support these fundamental governmental interests.

Although NGI will not provide funding support for applications per se, the initiative will partner with the application communities -- Federal agencies, the public sector, and private companies -- to incorporate new networking technologies and capabilities developed under NGI Goals 1 and 2 into applications of importance to each community and which the community cannot achieve over today's Internet. The technology community will derive technologies and services of the next generation Internet from essential and common features required by the applications demonstrated under Goal 3.

Strategy for Goal 3

While the applications that will benefit from the Next Generation Internet may span the entire range of human activity, there are several foundation-applications that are fundamental to large classes of applications. These foundation-applications are above network services (such as IPv6, Quality of Service, etc.), but are not tailored to only one domain. Two classes of applications have already been accepted as foundation-applications.

1. *Distributed computing* applications recognize that the network seeks to provide very high bandwidth coupled with low latency close to that determined by the speed of light. Examples of specific applications currently incorporating distributed computing include global ocean-atmosphere climate models, quantum mechanical materials models, and coupled hydrogen-radiation transport models.

2. *Collaborative applications* require moderate to high bandwidth and also the ability to reserve a piece of the network pipe for the video and audio streams regardless of what other processes may be using the net. Examples of specific applications currently incorporating collaboration include remote use of experimental facilities, distance learning, and collaborative engineering design.

Other foundation-applications will be identified as the program progresses. Candidates to be added to the list include:

- a. National security response and crisis response which require nomadicity and dynamic network reconfiguration.
- b. Distance education and service to the citizen which require extreme scalability at nominal cost.
- c. Teleoperation which requires extreme reliability coupled with guaranteed delay bounds.

These foundation-applications are independent of any one knowledge domain, but can be extended by mission agencies to suit their own application-specific needs. Taken together, these foundation-applications will be chosen to completely test the new network capabilities developed by the NGI. If these applications are successful, they will demonstrate that the set of new services are robust, complete, and ready for commercialization.

The strategy for achieving Goal 3 is to identify a small number of demonstration applications for each participating mission agency and other significant applications from academia and industry. Applications will be chosen to leverage significant application funding from the respective agencies, industry consortia, or other university research funding sources. NGI will provide funding for specific testbed connectivity, functionality, services, and software that maximize the value of the infrastructure connectivity and services deployed by this initiative.

Each demonstration will partner advanced networking technologies with advanced application technologies. Each community will bring its knowledge, skills, and methods to the partnership. Each application organization will have to provide the bulk of the resources needed to implement its application and will be required to work within the framework of the NGI initiative to develop and demonstrate its application over the high-performance networking technologies provided by other parts of the initiative.

Potential sponsoring organizations will choose applications to demonstrate within the NGI because their candidate applications require next generation internetworking technology to demonstrate advanced functionality and performance. The proof-of-concept opportunities provided by this initiative will give substantial visibility to new approaches for meeting important Federal missions as well as those of other institutions. For this reason, it is essential that the NGI select application demonstrations that will be perceived as important by the private sector and the general public.

This strategy of required user-organization funding will accelerate transition of successful applications to the mission agencies. If the applications delivered under Goal 3 turn out to be faster, better, or cheaper, it will be in the agencies' own interests to use these applications, thus improving the delivery of mission services to their user communities.

Metrics for Goal 3

The primary metrics of success for Goal 3 are the following:

- **Fraction of institutions demonstrating high importance applications.** For NGI to be successful, nearly all of the participating NGI sites must be developing and demonstrating at least one high-importance application. (There may be a few participating institutions that only develop technologies under Goal 2; those technologies would be provided to organizations developing applications under Goal 3.) Each application proposed for the NGI initiative would be required to define application-specific success metrics. These metrics would be evaluated and reported for each application with validation being a required part of the application demonstrations. NGI will maintain a web site that reports successfully validated application demonstrations.
- **Value of applications in testing network technologies.** The objective of the technologies and networks in Goals 2 and 1 is to enable applications. Each application project proposed for this initiative would identify the required NGI network technologies and would be required to develop measurements of the effect of those technologies on the application. Even qualitative technologies such as security and network management would have definable effects on applications, and these effects can be assessed by appropriate means identified by the application projects. The measurements of these effects would be reported as part of the validation process for each application.
- **Demonstration of new paradigms for network use.** It is anticipated that several unforeseen opportunities will emerge from the experimentation and applications of the NGI networks. These will result in new paradigms that enable a new class of applications and technologies. In the past, examples have included things such as sophisticated point-and-click interfaces or web browsers and their successors. This metric will define, document, and demonstrate these new paradigms.



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2.5 Five-year Roadmap

[This roadmap will be created from analysis of the Goal 1-3 action plans, expected deliverables, budget, and management plan. The roadmap will summarize what will be achieved each year, and especially what concrete deliverables will be achieved early (i.e., Year 1 or Year 2).]

Five Year Roadmap
(to be supplied by implementation team)



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2.6 Transition Strategies

This initiative is designed throughout for transition to the private sector. Specific strategies to accelerate transition of the deliverables resulting from each goal are summarized in Sections 2.2 through 2.4 and in the action plans for the specific goals. The broad agenda for transition includes the following elements.

- Collaboration among research universities, Federal research institutions, and industry
- Multiagency program management and execution
This requires tighter coordination and therefore more collaboration because the networks, middleware, services, and many applications must be interconnected and interoperable.
- R&D partnerships with industry and research universities-extensive use of grants and cooperative agreements requiring private investment
- Widespread leveraging of existing programs for network connections and services-vBNS/NSF connections, NASA NREN, DOE ESnet, DARPA ATDnet, CAIRN, applications
- Potential international collaboration
- Understanding of the economics of the Internet industry
Focus resources on areas where Federal involvement is needed to influence technology and evolution. For examples, existing ISPs focus primarily on meeting today's operational needs; telcos and telecommunications equipment industries focus on building faster pipes.
- Insight and expertise of agencies with high-demand applications
These agencies understand what technology areas are crucial to a massive scale-up of today's Internet and elimination of its systemic problems.
- Mentoring and co-op programs developed with Federal research institutions, industry and university resources
- Required open standards development, specification and dissemination via processes implemented through organizations such as the IETF
- Focus on internetworking technology integration, performance, and multivendor interoperability (whereas each commercial vendor interest by itself might be to focus on proprietary solutions)
- Significant concern from the beginning for security, dependability, system scalability, manageability, integration, and interoperability

This agenda will assure that NGI-delivered technology is pragmatic enough to be transitioned successfully to the real world by industry partners and research entrepreneurs.



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3. Expected Deliverables

The NGI initiative will deliver new networking technologies that have the potential to advance human communications, access to information, and productivity as greatly as did the current Internet. These technologies will make the future Internet as different from today's Internet as today's is from the telephone. The resulting new capabilities will dramatically improve the way in which new Federal applications will be developed and used in the future, allowing us, for example, to break the remaining barriers to activity-at-a-distance. The community that will emerge from this program will help drive these innovations to the commercial market.

The NGI initiative will develop and demonstrate new technologies; the underlying partnerships will be crafted and managed to promote the rapid transfer of these technologies into applications, both public and private. The new capabilities will attract Federal and federally supported research networks to NGI technologies. Widespread adoption will elevate the technological foundation on which to build qualitatively improved Federal applications and government information service delivery. For example, improvements will be implemented in new services dealing with civil and natural emergencies. These services may require five-minute response from initial data collection through analysis, event identification, local authority identification, and notification. Such capabilities would dramatically reduce losses.

This Federal program will fund the deployment of at least 100 high-performance connections to research universities and Federal research institutions, and these will also be interconnected to the larger national information infrastructure. The result will be a very-high-speed network that will be available for advanced network concepts research and for focused high-end application demonstrations. Leverage will be enormous, since a great deal of the research conducted for the Federal agencies involves the faculty, students, and staff of these institutions.

At least 100 science and engineering applications will successfully use these connections. University and national laboratory research in all scientific disciplines will benefit greatly from the enhanced data exchange capability, researcher interaction, and collaboratory tools and environments that result from this program. Testbed applications for improving Federal information services in at least 10 application areas will also be demonstrated.

During the first year, at least thirty government-industry-academia R&D partnerships will be created to leverage this program funding by at least two-to-one. This program will also leverage existing Federal funding to establish multi-discipline research and education programs in information systems design and management. These will use Federal research institutions, industry, and university resources to develop mentoring and cooperative education programs.



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4. Expected Benefits

The NGI initiative will benefit society at large by providing technology that enables widely available and rapid access to information and services in many locations and forms.

As an example, consider the area of crisis management. When a crisis occurs, it will no longer be necessary to spend weeks or months assessing damage and initiating Federal aid. With advanced networking, government information services will provide key decision-makers with immediate information on the scope and severity of an emergency whether it be a hurricane, tornado, earthquake, oil spill, or airliner crash. Instead of spending hours or days traveling to the scene and assembling a team, the crisis manager will have the needed information available instantly with required security. Instead of searching local records and negotiating with local officials for access to data as was required after hurricane Andrew, advanced networking services will allow the local networks to be quickly reestablished, and provide the emergency manager with secure access to information as needed. National security systems will use these same technologies to respond to domestic and international security emergencies.

Telemedicine is a second critical area that will benefit society while also driving the development of advanced networking technologies. Advanced telemedicine will improve the quality of life in all regions, not just those remote from current medical services.

Another benefit of this program will be an improvement in knowledge discovery and dissemination. More effective and efficient knowledge discovery and information dissemination will benefit research areas as diverse as energy, the environment, and biomedicine. Education, including distance learning, will benefit from advancing the NGI suite of technologies. Together, these advances will drive corresponding improvements in the practice and services of all sectors.

Scientists, who are limited today in their ability to control even a single instrument through the Internet, will be immersed in a "collaboratory" environment where they will have interactive capabilities to work with large scientific facilities, supercomputers, data banks, digital libraries, and collaborators integrated into a seamless virtual environment. The impact on the productivity will be substantial when scientists can observe and control massive experiments in real time, rather than waiting for an off-line analysis to suggest what went wrong yesterday. Virtual communities of collaborators will lead to greater insights and new approaches.

This initial deployment of the NGI will spur and leverage more significant secondary deployment of twenty-first century networks throughout the U.S. These deployments will create an environment that qualitatively differs from today's: it will encourage more creative and forward-thinking solutions for improving education and knowledge discovery at all levels.

The resulting high-performance network infrastructure will also function as a distributed laboratory and help improve the U.S. R&D effort. The NGI ultra-high-performance network infrastructure will enable leading-edge data communications research into the properties of very-high-speed networks themselves. It will also lead to a better understanding of future high-quality multimedia and real-time networks.

NGI will have important benefits for both the public and the private sectors of the economy. All citizens will benefit from improved communications, and better information will permeate our daily lives. Networks will

improve the nature of telephonic communication both at work and at home. At work we will receive information more quickly and reliably; at home our Internet experience will be enhanced by faster communications, the ability to guarantee an acceptable line speed, and appropriate security protections. New applications, emerging from the availability of much faster, more reliable network services, will enhance our lives in unimagined ways. By partnering with colleges and universities, the process of developing these technologies will educate a new generation of Americans knowledgeable in the communications technologies required to thrive in the 21st century.

As these students move into industry, our national economic and technological competitiveness will increase. Finally, just as advanced networking provides exciting opportunities to improve the efficiency of government, so too will it make businesses more effective international competitors.

The Internet developments of the last decade have helped to propel the U.S. to a commanding lead in information technologies. The technology developed under this initiative will enable U.S. industry to develop hardware and software required to enhance our worldwide leadership in advanced networking services and applications.



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5. Management

The Next Generation Internet Program will be coordinated within the framework of the National Science and Technology Council (NSTC). The Committee on Computing, Information, and Communications (CCIC) will be responsible for the overall high level NGI strategy. The Computing, Information, and Communications (CIC) R&D Subcommittee is responsible for coordination across program component areas. The Large Scale Networking Working Group (LSN) is responsible for the implementation strategy of the NGI. A small, integrated NGI Implementation Team will take primary responsibility for implementing the approved plans under the direction of the LSN Working Group.

In particular, the NGI Implementation Team will:

- contain one member from each of the funded agencies plus an applications advocate who will provide linkage to NGI applications partners and to the CCIC's Applications Council
- use advanced networking and computing for effective coordination and communications
- answer to the LSN Working Group as a team (as well as to agencies as individuals)
- operate as an integrated project team for the overall NGI initiative
- be jointly responsible for execution of approved implementation plans, initiative management and evaluation, and other activities as required for successful implementation
- establish contributing partnerships and relationships
- recommend funding mechanisms and serve appropriately in the selection process.

The LSN Working Group, under the CCIC process, will:

- be responsible for strategic planning, marketing, and liaison for the NGI initiative
- champion and oversee the NGI Implementation Team
- provide a forum for all participating agencies whether directly funded by the initiative or not
- report to the CIC R&D Subcommittee of the CCIC.

As directed by the CCIC and the R&D subcommittee, the LSN will consult with the Presidential Advisory Committee on HPCC, IT, and NGI and other existing high-level, advisory groups as appropriate to facilitate and focus the broad community input and coordination that will be necessary for success. The LSN may charter special teams from the community as required to deal with specific issues and projects.

The LSN will actively seek opportunities for outreach with industry, education, and private industry through existing programs such as Small Business Innovation Research.

The directly funded agencies will, of course, also participate in the oversight of the NGI implementation team by, among other things, the approval processes required to expend agency resources in support of the NGI initiative.



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6. Action Plan

This section expands on the description of the NGI goals laid out in section 2 and contains more technical information. Because it is written primarily for a technical reader, acronyms and terms of art are used. It presents detailed issues, strategies, and milestones.

6.1 Goal 1: High-performance Connectivity

Develop the next generation network fabric and connect universities and Federal research institutions with rates that are 100 to 1000 times faster than today's Internet. This network fabric will connect at least 100 research institutions at speeds that are 100 times faster than today's Internet, and on the order of 10 research institutions at speeds 1,000 times faster.

This goal addresses end-to-end connectivity (to the workstation) at speeds from 100+ Mb/s up to 1+ Gb/s. Although some networks have already achieved OC12 speeds (622 Mb/s) on their backbone links and some experimental links are running at 1+ Gb/s, end-to-end usable connectivity is typically limited to 10Mb/s or less because of bottlenecks or incompatibilities in switches, routers, local area networks, and workstations. As a result, development of important applications requiring high-speed, reliable connections is frustrated, and the promise of the Internet is unrealized. Goal 1 addresses these shortcomings by developments and demonstrations to achieve two sub-goals.

- **Subgoal 1.1 (high-performance connectivity)** is a large-scale demonstration network fabric that would function as a distributed laboratory running at 100 Mb/s end-to-end and that connects 100+ institutions involved in 100+ significant applications. This demonstration is large enough to provide scalable prototype tests of required hardware, software, and protocols. This demonstration will provide sufficiently reliable support for the chosen applications to demonstrate their utility for the future commercial Internet.
- **Subgoal 1.2 (next generation network technologies and ultra-high-performance connectivity)** addresses advanced network technology development and end-to-end connectivity at 1+ Gb/s. Because of its greater cost and engineering difficulty, this goal will be achieved in a smaller wide-area demonstration/laboratory involving on the order of 10 institutions and applications. Some of these applications will involve research into the properties of very-high-speed networks. The reliability of the network for Subgoal 1.2 is expected to be lower than for Subgoal 1.1. Therefore, application experiments in this laboratory should not require high operational reliability.

High-performance (100x) Connectivity

Technology Problems

The challenge is to achieve 100+ Mb/s between end-users' desktops in a wide-area environment.

Needed technologies include:

1. Optimized and enhanced workstations that can well-utilize high-speed network access
2. Low-latency, high-speed network devices
3. Appropriate security at the network level
4. Distributed network management
5. Protocols to support national-level end-to-end Quality of Service (QoS)
6. Protocols and architecture that scale to meet national needs
7. Interoperability across heterogeneous networks and technologies
8. Architectures that support network survivability
9. Interoperability at layers 2 (e.g. ATM) and 3 (e.g. IP) between carriers and ISP's.

Solutions & Action Plan

In order to provide the required reliable, secure connectivity at the higher speeds (100+ Mbps) to a large community in a cost-effective manner, the Federal government will encourage industry to cooperate more closely so that the deployed networks are interoperable. The action plan for this effort includes having the Federal government provide incentives and opportunities for interoperability demonstrations, promote standards groups (but not lead them), and procure systems and networks only from vendors who have demonstrated interoperability. This will tend to encourage the industry towards development of interoperable networks and components.

Several existing high-speed Federal networks will provide the basis for the 100x testbed, viz. vBNS (NSF), ESnet (DOE), NREN/NSI (NASA), and DREN (DoD). Because these four networks are contracted from three different vendors, their interconnection will provide tests of interoperability. The Federal government will provide seed funding and enter into research collaborations to accelerate and expand the existing program of high-performance connections to link the 100+ research institutions and industrial partners into a network of networks. Specific actions and timetable include the following.

- Develop a funding and implementation model that promotes participation from multiple vendors (1997-98).
- Issue joint-agency solicitation for testbed participants (late 1997).
- Attract key government, university, and industry partners (early 1998).
- Provide mechanisms to interconnect Federal research networks and their carriers at high performance levels (1998).
- Leverage partner investments to provide target OC3 connections to sites using OC12 national infrastructures (1997-99).
- Implement an interoperable network of networks (1999).
- Test and deploy security, Quality of Service, and management tools (1998-2000).
- Cooperate in international connections appropriately to meet the needs of U.S. partners and address, in general terms, the international aspects of the connectivity (1998-2000).
- Develop a transition plan in coordination with industry to enable transfer of appropriate technologies, standards, and concepts to agencies, industry, and the commercial Internet (1998-99).
- Implement network security technologies and policies that can accommodate cross-agency requirements (1999-2001).
- Upgrade to 100+ Mbps connection to end-users' desktops in a wide-area environment using OC48 to OC192 national infrastructures (2001-02).

The Federal government will partner with research institutions and industrial companies to establish a system of high-performance network interconnection points (e.g., gigapops) that will

- Provide for vendor-neutral connection and access to high-performance networks
- Provide direct access to very-high-speed experimental applications and facilities
- Provide access to the commercial Internet in a way that avoids competition with the Internet industry
- Provide a national-scale platform for the migration to new protocols and technologies, performance measurements, network management, etc.

This 100+ site network of networks will be used both to test advanced Internet protocols and services and to provide a reasonably stable platform for testing high-performance network applications. Care will be needed to balance and serve both of these objectives, because they may conflict with each other.

Ultra-high-performance (10s 1000x) Connectivity

Technology Problems

1. Fast switching, routing, multiplexing, and buffering of data streams
2. Ultra-high-speed network management and control over multiple domains
3. Cost effective broadband access to high end users
4. Network management and policy issues at national levels

Solutions & Action Plan

Networks operating at OC-48 and above face all the issues raised for those operating at OC-3 and above. Several additional difficulties arise which require research. High performance switching (or routing) at these speeds is extremely difficult. Transmission issues are being actively researched through several programs. Candidate technology is a combination of optical WDM (wavelength-division-multiplexing) and IP/ATM/SONET switching. These provide a credible starting point for achieving the objectives of the Initiative.

It will be important to test out ultra-high-speed network technology in wide-area network testbeds. However, the very high cost of OC-48 circuits may force us to regional, instead of nationwide, testbeds. A potential starting point is the DoD ATDNet in the Washington D.C. area. ATDNet currently connects several defense agencies with a OC-48 ATM/SONET ring. Other sites (academia and Federal research laboratories) could also be connected with very high speed links. A key challenge in implementing this subgoal will be achieving true wide-area networking at acceptable cost. Participation and cost-sharing by the telecommunication and computing industries in this research program will help the NGI afford the goal.

The initiative will assist in the development of this technology by:

- Partnering with sites that are experimenting with multi-gigabit networks in selected labs, campuses, and regions (1998-99)
- Testing computer-to-computer links at OC-48 or higher levels (2000).
- Providing support for interconnectivity and co-existence between the ultra-high-performance network and the high-performance network (1999-2000)
- Testing protocols, security, and network management tools for ultra-high- performance networks (1999-2001)
- Providing mechanisms for reserving special capacity on demand for dedicated bandwidth, special protocols, etc.(1999-2001)
- Partnering closely with carriers, vendors of switches, routers, etc., in standards definition, performance measurements, network management, security, etc., and in pushing performance limits (1998-2002)
- Accelerating research and development in selected core technologies (e.g., Tbps switching, routing, transmission, and scalable data I/O) (1998-2002)



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6.2 Goal 2: Advanced Network Service Technologies

Promote experimentation with the next generation of networking technologies.

Emerging technologies could dramatically increase the capabilities of the Internet to handle next generation applications. For example, real-time network services can help to support high-quality video-conferencing applications. There are a variety of research challenges that need to be addressed to provide such services for the anticipated network environment; this environment includes both an increasing number of high-end users and a large number of low-end users who in aggregate produce a large amount of traffic. The Federal government can accelerate the development of emerging applications by providing support for testbed research networks that incorporate new network service technologies. These networks will also accelerate the introduction of new applications and technologies into commercial networks.

This section outlines an overall strategy for developing and deploying advanced network service technologies and gives action plans for the specific issues related to: definition and implementation of the new services, end-systems, and overall system considerations. Finally, the costs of achieving this goal are estimated.

Overall Strategy

The advanced networking service technology goal will promote the early deployment of research prototypes, coordinated by a vendor and research community network design board. This design board will influence vendor implementations in each service area, ensuring, for example, that QoS guarantees and appropriate security are present. Early feedback from application experiments will be used to inform architecture development. Implementation priorities will be dynamically updated by feedback from the participating communities.

The network service technology strategy will stress

- encompassing a variety of technologies that "push the envelope" including allocation and sharing bandwidth and other network resources
- supporting configurations for a variety of high-performance network and experimental ultra-high-performance network uses
- building evolvability and robustness into networks
- developing interoperability as seen at the user level in spite of many dissimilar media, protocols, QoS specifications, etc.
- assuring interoperability at the IP/bearer service level, and striving for other-layer (e.g., ATM) interoperability
- designing for network management services from the beginning, including network management for IPv6 and considering similar issues for non-IPv6 environments (e.g., ATM and self-describing packet/active nets)
- promoting capabilities for authentication, integrity and privacy
- promoting capabilities for network performance measurement and statistics gathering.

Definition and Development of Network Services

The definition and development of advanced network service technologies will be centered around a variety of qualities of service (QoS) and techniques for guaranteeing that they can be realized in the network. This will involve developing and implementing a QoS architecture and the associated protocols.

QoS Action plan

The key to satisfying the demands of advanced applications is to develop a quality-of-service architecture that can be tailored to meet different requirements. By working with the Federal research institutions, universities, and industry, the design board will develop a plan for a QoS architecture.

The architecture will address areas such as

- security and robustness
- configuration control
- reliable delivery
- support for audio, video, and other real-time applications
- jitter and delay
- minimum and maximum generated bandwidths
- priority, costing, and administrative accounting (differential levels of service)
- QoS APIs
- characterization of network services (semantics, terms)
- support for broad set of QoS parameters
- mapping QoS parameters and supporting signaling across network and application tiers
- supporting bi-directional exchange of state and management information (for example, applications can change their QoS requirements during a session, and applications can be informed that QoS parameters have changed in the underlying network)
- resource reservation and usage accounting as enabling mechanisms
- uniform semantics for describing network engineering parameters: bandwidth, burst error rate, etc.
- AUP and policy as QoS parameters (for example, use of QoS to divide traffic into high-performance vs. experimental ultra-high-performance network), production vs. R&D traffic, or other appropriate policies.

Protocol Action Plan

The Federal government should encourage development of international standards for protocols and should provide seed money for early deployment. Major protocol needs for supporting high-end networks include: multicast, reliable transport, support for security, efficient interaction between level 2 and level 3, and support for advanced computing architectures.

Actions required include

- recommend early adoption of advanced protocols for supporting program goals
- switch and router network management protocols and databases that support both application and network administrator configuration and management
- evolvability built to protocols from the beginning
- interoperability and peering negotiation protocols and support
- IPv6
- IPv6 and ATM
- ATM signaling protocols
- QoS RSVP over ATM QoS
- self-descriptive network protocols
- combining level 2 and level 3 techniques in concert -- routing making use of switching capabilities to achieve configuration goals, etc., as well as the necessary integrated analysis and management tools
- multicast security
- mobile IP (nomadicity; resource discovery etc.)
- efficient group communication (e.g., multicast)

- scaling of end-to-end services over high speeds -- TCP, reliable multicast; also burst error rate.
- scaling of level 2, 3, and 4 with respect to congestion and big pipes
- support for intrusion detection, while ensuring privacy
- tightly coupled computing architectures.

End-System Considerations

The computers that are interconnected by the next generation Internet will require research and development to assure that the services delivered by the network can be well-utilized. Individual end-systems, their operating systems, and the collective distributed environment will be considered.

Operating Systems Action Plan

The current operating systems available to the general end-user limit the rate at which interfaces can operate. They were designed at a time when end-user computers were mainly stand-alone and slow and links operated at less than 10 Mb/sec. Networks were expensive and very limited and did not address network security issues. This is not appropriate as higher speed links become available and higher CPU speeds become the norm. More efficient operating systems and interfaces are required. The current personal computer industry is focusing on operating system ease-of-use and not on dramatic operating system speed increases by more compact coding. Operating systems are getting ever larger and require more CPU speed just to keep up to an acceptable level of performance. Also, the delivery of data with finely-tuned QoS guarantees is useless unless the data can survive the last bus transfer -- the delivery of the data from the network to the end-user or application.

In order to accelerate the development of more efficient operating systems, the Federal government needs to be forward looking, provide seed funding, and work with software and hardware developers to do R&D on network interfaces and operating systems to allow higher throughput at the desktop level.

Collaborative And Distributed Environment Action Plan

Collaborative and distributed environments require advanced networking technologies to operate within strict QoS constraints. Environment designers should review results of application experiments and coordinate with security and QoS architects. The areas to address include

- built-in security, protocols, QoS, Net management
- caching (soft state of WEB information, Directory/DNS, QoS, routing information, etc.)
- ability to monitor and query to query the network by applications
- object and key infrastructure
- negotiation of end-to-end environment services, costs, etc.
- characterization of services, systems, accounting and other policy issues
- synchronization over a wide spectrum of capabilities (wireless, supercomputer, etc.)
- scalability of services over millions of nodes
- mobile code support, agent-based computing for images, video
- mobility--untethered (wireless), nomadic, mobile IP, mobile networks, mobile code.

Overall System Considerations

The next generation Internet will be a complex system composed of many components. Security and scalability will be considered from the initiation of the project in order to control complexity, network management, engineering design, and service architectures.

Network Management Action Plan

One objective is to integrate visualization, modeling, monitoring, and control ideas from the network research community with services provided by the individual network technologies and providers. The design board should develop an architecture for interoperable network management and engineering. Compliance with this

architecture will be required for the high-performance network and be encouraged for the ultra-high-performance network. The government should guide the development of suitable network management technologies by the provision of seed funding to selected industry and university researchers. The Network Management Action Plan must be closely coordinated with the Security Action Plan to assure the security of network management and to address the management of network security.

Engineering Action Plan

The current Internet was developed initially as a loose network of networks. It was never envisioned as a tightly integrated system. The network service technology goal will provide the framework for properly engineering the Next Generation Internet as a "heterogeneous system" (that is, diverse but properly integrated). The Federal government will provide the impetus for development of advanced technologies in conjunction with our Federal research institutions, universities, and industry for this heterogeneous system.

Areas that will be addressed include

- status, statistics, monitoring, analysis, simulation, modeling
- network management built in from the beginning
- interoperability (across different carriers, media, speeds, administrative domains of security, QoS, other policies, and evolvability)
- high-performance and experimental ultra-high-performance networks over the same infrastructure
- configuration control, signaling, diagnostics, testing
- "costing" (cost-benefit) support
- runtime management--ability to maximize service among competing requirements
- engineering issues (performance measurement and validation, test, diagnosis, repair, survivability, maintenance of priority channels, minimal essential infrastructure, redundancy, etc.).

Security Action Plan

Security is a cross-cutting architectural characteristic supported by specific technologies for authentication, integrity, confidentiality, and availability.

The new network should be a testbed for the early implementation of an interoperable security architecture. The design board should be convened to recommend a simple plan and supporting technologies. The plan should encompass heterogeneous mechanisms within a generic policy. Members of the next generation network community should be able to communicate securely across separate administrative domains. The areas that will be addressed include:

- database support (e.g., directories, DNS, CAs, key distribution and management)
- authentication, access control of more than humans (e.g., places, PCs, objects)
- multiple policy characterization, support, and implementation
- what security attributes and semantics are agreed to; how to characterize policy
- end-to-end interoperable authentication, confidentiality, and integrity
- management of security
- interoperable PKIs

Scalability Action Plan

The NGI will be the basis for an eventual Internet that will be orders of magnitude larger than the current Internet. Scaling the supporting services up to such a level will stress even a hierarchical design. NGI must provide research for assuring a smooth development strategy. This constraint indicates a mixed strategy of hierarchies, caching, dynamic configuration, and information compression in the following key areas:

- **Routing** -- efficient routing table representation, update, and transmittal are essential to NGI. Research should cover engineering models and simulation of huge, loosely clustered routing protocols in order to learn the most efficient ways to represent and update routing tables.
- **Names and other end-system attributes** -- global directories of end-system information must be ubiquitous, accurate, and available. Scaling issues include caching, information compression requirements for server machines.
- **Strategies for efficient transport** -- network routers may need to acquire information about data flows in order to schedule resources for them. With more end-sites, more information must be stored inside the network about existing flows. Will the infrastructure have the capacity for the data transport and the detailed flow information?
- **Management and Engineering** -- research is needed into techniques for predictive performance modeling of huge networks. Additional research is needed to understand how much information must be collected dynamically from the running network, how to organize it, and how to use it to understand the global system.



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6.3 Goal 3: Demonstrate New Applications

Demonstrate new applications that meet important national goals and missions.

Higher-speed, more advanced networks will enable a new generation of applications that include scientific research, national security, crisis response, distance education, environmental monitoring, and health care.

Many agencies have critical signature applications that will benefit from advanced networking services and capabilities. Both the Federal government's information technology services and the federally supported R&D community have networking requirements that cannot be met with today's networking technology. Higher speed networks with more advanced services and functionality will enable a new generation of applications that support fundamental governmental interests including national security, disaster response, scientific research, distance education, environmental monitoring, prediction, and warnings, and health care.

As the NGI initiative develops capabilities to expand the Internet, demonstration applications will take advantage of these new services. It is expected that additional agencies will participate in these applications. For example, the National Institutes of Health has already indicated its intention to join the initiative. Important NGI applications prototypes will test these new capabilities to ensure that the protocols developed in Goals 1 and 2 are complete, robust, and useful in real applications and to provide a roadmap to future governmental and commercial services.

Success in reaching Goal 3 depends on success with Goals 1 and 2. Hence, Goal 3 drives the selection of the capabilities and designs for the other goals. In addition it requires the integration of the new networking capabilities with the application domain.

Although this program will not provide substantial direct funding for applications, it will partner with and leverage resources of the application community to incorporate new networking technologies and capabilities into applications to improve the R&D and service delivery to the public and private sectors. The essential and common features required by applications and demonstrated by this program will be identified and included in the feature set available via the Next Generation Internet.

Action Plan

The application demonstration program will select key applications that require advanced networking technologies, are ready to deploy these technologies to improve the application service delivery, and can be used as a roadmap to develop other critical applications.

Selection Criteria

This program will select partnerships for application demonstrations and testbeds which are not only critical governmental needs, but also provide robust, complete tests of technologies that are extensible and adaptable to other applications. In addition, the program will select applications as the underlying networking technologies begin to enable the necessary infrastructure.

Criteria for selecting applications are the following:

1. The application domain is an important Federal mission and is recognized by the public as important.
2. The application demonstration requires high-performance internetworking technologies and services that will result from NGI R&D.
3. The networking concepts and technologies embodied in the application testbed are extensible to other application domains and scalable to the future commercial Internet.
4. The application community will supply resources for the application-specific technologies component of the testbed.

Each demonstration will partner advanced networking technologies with modern applications technologies. Each community will bring its knowledge, skills, and methods to the partnership. The applications organization will provide the bulk of the resources needed to implement the application, and it must be willing to work within the framework of the NGI initiative to develop and demonstrate its applications over the high-performance networking technologies provided by other parts of the NGI. The applications demonstrations will primarily demonstrate proofs of concept. Many will suggest new ways for the application organizations to meet their mission needs. All parties will have to recognize that the demonstrations are part of a research effort and, as such, will initially be built on less-than-fully-robust technologies and be operating in less-than-bulletproof networking environments.

Potential sponsoring organizations will choose applications to demonstrate within this initiative because their candidate applications require the next generation internetworking technology to demonstrate advanced functionality and performance. The proof-of-concept opportunities provided by this initiative will give substantial visibility to the new approaches for meeting important mission needs that are being undertaken by the sponsoring Federal agencies and other institutions. For this reason, it is essential that this initiative select application demonstrations that will be perceived as important by the private sector and the general public.

The other parts of this initiative will benefit from the selection of applications that drive the networking technologies. That is, it will be essential to select applications for demonstration under this initiative that well-utilize and even stress the networking technologies being developed by the other parts of this initiative. Point design studies can determine the maturity of the suite of required network services.

Sample Applications

Suggested demonstrations cover a wide spectrum of capabilities ranging from time-critical applications such as crisis and national-security responses to broad collaboration in areas as diverse as health care, education, and research. Telemedicine extends collaboration adding robustness, security and reliability.

Application testbeds serve as platforms for proof-of-concept demonstrations. They tie together networking technologies, test the completeness of NGI protocols, and force the technologies to operate in real situations. By forcing technologies to work together in complex situations, applications stress the co-operability and interoperability of the developing suite of advanced networking services. In addition, effective demonstrations showcase new network capabilities, resulting in new acceptance and even enthusiasm for these important advances.

Potential applications include:

- **Health care** -- Doctors at university medical centers will use large archives of radiology images to identify the patterns and features associated with particular diseases. With remote access to supercomputers, they will also be able to improve the accuracy of mammography by detecting subtle changes in three-dimensional images.
- **Crisis Response** -- Crisis managers will access a wide range of information under the most difficult and unpredictable circumstances. Networks will be self-configuring to enable rapid return of services after a disaster; information from multiple levels of government and the public sector will be immediately available. And the results of remote models will be available for failure diagnosis and prediction of effects during natural or man-made disasters.
- **Distance Education** -- Universities are now experimenting with technologies such as two-way video to remote sites, VCR-like replay of past classes, modeling and simulation, collaborative environments, and on-line access to interactive, multimedia instructional software. Distance education will improve the ability of universities to serve working Americans who want new skills but who cannot attend a class at a fixed time during the week.
- **Scientific Research** -- Scientists and engineers across the country will be able to work with each other and access remote scientific facilities as if they were in the same building. "Collaboratories" that combine video-conferencing, shared virtual work spaces, networked scientific facilities, and databases will increase the efficiency and effectiveness of our national research enterprise.
- **Climate Research** -- Scientists, researchers, and policy makers will be able to examine the effects of proposed actions on the long-term evolution of our environment. Models will become available to and usable by all interested users.
- **Biomedical Research** -- Researchers will be able to solve problems in large-scale DNA sequencing and gene identification that were previously impossible, opening the door to breakthroughs in curing human genetic diseases.
- **Environmental Monitoring** -- Researchers are constructing virtual worlds to model and monitor defined ecosystems. For example, one project models the Chesapeake Bay ecosystem, which serves as a nursery area for many commercially important species.
- **Manufacturing engineering** -- Virtual reality and modeling and simulation can dramatically reduce the time required to develop new, higher-quality products in integrated process/product design systems. Process monitoring at a distance would enable system-wide quality control and efficiency optimization for international producers.

Additional applications will be identified through public processes such as a call for proposals from the university or private sector communities.

Characteristics and Requirements of Demonstration Applications

New network technologies and services will result in large performance improvements in Federal government applications, thus enabling the re-engineering of critical mission services and functions. New network technologies will also enable a whole new generation of such Federal applications.

This new generation of applications will require very different network capabilities than are used in similar applications today. The following list provides a sampling of the critical capabilities that will be needed before many of these network-based applications can be put into production environments. Demonstrations and testbed environments will be established to evaluate new capabilities and to provide a real-world demonstration of these new capabilities across the spectrum of Federal applications and government information service providers. (Much of the following list has been extracted from two recent National Research Council reports on

"National Collaboratories" and on "Computing in the Extreme." A more extensive list of applications needs is in Appendix 1.

- **Security** -- Telemedicine and electronic commerce, for example, will rely on the capability to maintain privacy and the confidentiality and integrity of personal data.
- **Controlling remote instruments** -- Communicating with distant fellow workers is required for aerodynamic design and for using remote science facilities, such as using an advanced light or photon source across a network.
- **Visualization** -- Remote visualization technology is important for seeing what is being controlled at a remote facility or for viewing the results of computational simulations. Advanced visualization technologies such as network integrated immersive virtual reality devices will be needed to allow multiple design or experimental teams to work together across distances to simultaneously observe or analyze data, images, etc.
- **Scalability** -- Network technologies used by wide-area applications must be able to be scaled up to support applications at the national scale far better than is possible today.
- **Self-Organizing Networks** -- This capability provides for self-adaptation when the physical configuration or requirements for network resources have changed. Crisis management requires the ability to establish or reestablish networks in the field among managers, action agents (such as police, fire, health care), and situation-specific information providers.
- **Nomadicty** -- The ability to move resources as need dictates will become increasingly important. This will include "mobility of access rights" so the network will know how to treat a new resource. This may range from full rights to complete denial of access.
- **Reliability** -- When advance networking services are implemented, they will be fragile and suitable only for research, yet the designs must be scalable to full commercial and even military robustness.

Each of the application testbed demonstrations will involve many of the above and possibly other advanced network technologies and capabilities. The next generation applications will be designed to take advantage of these types of characteristics individually and in combination, thus making a qualitative difference in the selected Federal applications and services.

Each testbed will provide a complete system and infrastructure, possibly shared, for a specialized community of scientists or government information service providers. The testbeds will demonstrate large-scale collaborations or use of specific applications or services. Resources across these testbeds will be jointly sponsored and leveraged across application communities. Success of the testbeds will require interdisciplinary, closely coordinated teamwork among application users, providers, and technology developers.

Deliverables

- In conjunction with the CCIC Applications Council, identify high-priority mission applications which require advanced networking technologies and services. (1997)
- Determine technical dependencies from Goals 1 and 2; match applications demonstrations with those deliverables. (1998)
- Attract key application mission partners (1998)
- Demonstrate applications using the first advanced networking technologies (IPv6, ATM, QoS) (1999)
- Enhance application demonstrations as networking technologies evolve (security, nomadicty). (2000 - 2002)
- Leverage experience gained from early application demonstrations to develop and to demonstrate more complex applications. (2000 - 2002)



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Appendix 1 : Collected Requirements of Demonstration Applications

Below is a list of the network-level services required by the anticipated advanced applications.

- a. Security. Telemedicine and electronic commerce, for example, will rely on the capability to maintain privacy and the confidentiality and integrity of personal data.
- b. Data sharing. Digital libraries, other science and technology information banks, etc. will be required for network-based applications such as federated Genome Data Bases, Crisis Response, and Earth Observing Satellite data used throughout the Space and Earth Sciences community.
- c. Software Sharing. The capability for scientists at different locations to conveniently share software that supports data analysis, visualization, and modeling to all manner of remote collaborations.
- d. Controlling remote instruments. Communicating with distant fellow workers is required for aerodynamic design and for using remote science facilities, such as using an advanced light or photon source across a network.
- e. Visualization. Remote visualization technology is important for seeing what is being controlled at a remote facility or for viewing the results of computational simulations. Advanced visualization technologies such as network-integrated, immersive virtual reality devices will be needed to allow multiple design or experimental teams to work together across distances to simultaneously observe or analyze data, images, etc.
- f. Scalability Network technologies used by wide-area applications must be able to be scaled up to support applications at the national scale far better than is possible today.
- g. High End Computation and Computing resources. Testbeds will need to integrate supercomputers and computational technologies for a number of reasons. In remote experimentation, supercomputers may be used for real-time diagnostics to ensure that devices are performing within specification. In other forms of telescience, supercomputers may be used for instrument recalibration or for real-time modeling of experimental data.
- h. Self-Organizing Networks. This capability provides self-adaptation when the physical configuration or requirements for network resources have changed. Crisis management requires the ability to establish or reestablish networks in the field among managers, action agents (such as police, fire, health care), and situation-specific information.
- i. Nomadicity. The ability to move resources as needs dictate will become increasingly important. This will include "mobility of access rights" so the network will know how to treat a new resource. This may range from full rights to complete denial of access.
- j. Rapid resource discovery capability. Currently network administrators painstakingly document resources, assign rights, and monitor use. In the future, everyone will require the ability to discover network resources as needed. The most extreme case will be during the response to a natural disaster or other crisis.
- k. Portability and interoperability of applications. As networking and computing become more ubiquitous, we will increasingly work only with the end-user application requiring the idiosyncrasies of networks and computers to be transparent to users.
- l. Virtual Subnetworking. This provides the ability to establish specialized communities of interest. They may be a group of researchers collaborating on a climate model, a contractor and subcontractors working on a new product, or a task force developing a new policy.
- m. Ease of use. At heart of future networks will be ease of use. It will be as easy to add resource to our networks as it is to plug in a phone today.

- n. Reliability. When advance networking services are implemented, they will be fragile and suitable only for research, yet the designs must be eventually scalable to full commercial and even military robustness.



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Appendix 2: Agency Roles in the NGI

Each participating agency brings specific skills and experience to the initiative. These skills and experience provide an essential base upon which the initiative is built. The strength of this base allows projection of likely success for the initiative, without which the initiative would be much more risky. Specific agency strengths include:

DARPA: long-term, general expertise in networking research, general skill in high-end network technology and testbeds, experience in managing networks.

DOE: long-term experience in managing production and research networks, specialized skills in networking technology, great strength in mission-driven applications and in system integration.

NASA: experience in network management and in specialized network testbeds, strength in mission-driven applications involving high data rates, great strength in system engineering and integration.

NSF: special relationships with the academic community, experience in network research and in managing networks, great strength in scientific applications.

NIST: long experience in standards development, networking research, and in testbeds involving many industrial partners.

NGI FY98 Proposed \$100 Million Budget

(Dollars in Millions)

	DARPA	NSF	DOE	NASA	NIST
Goal 1: High Speed Connectivity	20	7	25	3	
Goal 2: Technologies	20	2	6	2	2
Goal 3: Applications		1	4	5	3
Total:	40	10	35	10	5

Note: future versions of this paper are expected to include funding from additional agencies who want to be part of the initiative, for example NIH has expressed interest in joining the NGI.



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Defense Advanced Research Projects Agency Role in NGI

DARPA NGI Goal

The FY98 Budget request includes \$40 million to support the participation of DARPA in the Next Generation Internet. DARPA's NGI goal is to develop advanced technology consistent with NGI subgoals 1.2 and 2, and facilitate (not develop) some ITO program demonstrations: Human Computer Language, Information Management, Information Collaboration and Visualization, and Global Mobile Wireless, in the NGI environment.

Tasks

There are three major tasks in this effort which will be accomplished in coordination with other DARPA networking research programs. These tasks are: SuperNet, QUORUM, and Network Management. Briefly, SuperNet addresses the development of advanced transmission and switching technology, QUORUM focuses on the intelligent access and negotiation of Quality of Service (QoS), and Network Management develops the tools for managing large scale heterogeneous networks. SuperNet is allocated \$20M and it corresponds to NGI subgoal 1.2. Quorum and Network Management are allocated a total of \$20M and these two tasks correspond to NGI goal 2.

1. SuperNet - This task addresses the development of broadband wide area network and local access, all-optical network technologies and ultrafast switching components

- **Broadband Local Access:** The DARPA Broadband Information Technology (BIT) program has developed the WDM broadband technology for the long haul and local exchange networks, but the broadband technology has not penetrated the access loop. This task seeks to develop the technology for pushing broadband access to the end users. This access could be terrestrial or wireless, depending on the location, the density, and the mobility of the end users. For the terrestrial network, we will examine the feasibility of WDM fiber to the building. For the wireless, we will explore the effectiveness of wireless high bandwidth trunking and networking among distributed local area users' facilities.
- **Wide Area Broadband Networking:** The BIT program will demonstrate WDM eight wavelength, 20 Gbps transmission and switching in a survivable ring configuration. This will expand this network to a wide area network with at least ten nodes. The network node could be a super computer center, a command center, or even a workstation. The target here is Gbps to the end user.
- **Ultra Fast TDM Networking Technologies:** While the BIT has invested some funding in ultra fast TDM systems (soliton type), this area is still largely unexplored. This class of network is important because the capacity of WDM system is subsequently limited by the optical amplifier bandwidth (~25 nm). As we scale up the number of wavelengths in a WDM system, the spacing between wavelengths will decrease and the crosstalk among channels will increase. This system crosstalk will eventually limit the scaling capacity of WDM networks. Ultra fast TDM systems use very narrow optical pulse (< pico second) and are usually single channeled. This task will examine the transmission, switching, amplification, synchronization, and buffering of these ultra fast optical pulse train.

- **Tbps Switching:** This task will develop the generation-after-next packet switching and multiplexing technologies. The switching architecture will be scalable both in terms of bandwidth and the number of input and output ports. The target is to develop a terabit per second packet switch with a hundred ports. The switching fabric will be strictly non-blocking and the switching hardware could be optical free space cross connection, CMOS or GaAs technologies. This task will also support the software development to enable a switch to share a connection among high end users without each user having to pay for the full connection. Lastly, this task will also support efficient multiplexing and demultiplexing techniques at the periphery of the switching fabric.
- **Intelligent Multiplexing:** This task will develop the technology to allow the network manager to intelligently share network resources to both high end and low end users. The network will know how to "throttle" the bandwidth of the pipe to accommodate end users in real time. Today's network can only allocate permanent virtual circuit to each type of users and this process results in very efficient usage of network resources.
- **Technology Demonstration and Field Trials:** Most of the technologies to be developed by the previous tasks are associated with the physical and networking layers. This task will seek collaboration with some of the ITO applications programs, for example, Human Computer Language, Information Management, Intelligent Collaboration & Visualization, and Global Mobile Wireless to demonstrate the next generation applications in NGI.

2. QUORUM - This task will develop the technologies which will allow end users to achieve predictable and controllable quality of services for critical Defense computing needs on a globally managed pool of geographically distributed resources.

- **QoS Architecture:** Develop the overall framework of models, languages, and protocols that permit distributed applications to specify desired QoS levels and to negotiate acceptable tradeoffs and confidence levels. It will further develop the algorithms that permit translation of high-level, application-specific views of QoS into low-level constraints on individual resources or services and monitoring technology to continuously measure delivered QoS and notify applications when QoS "contracts" can no longer be honored and renegotiation is necessary.
- **Translucent System Layers:** This task will populate the QoS Architecture with a new generation of layered distributed system software that overcomes the limitations while preserving the benefits of layered abstractions. These "translucent layers" will augment traditional functional interfaces with control interfaces to permit higher layers to impose QoS constraints or impart information necessary to meet the needs of higher levels. Dynamic adaptation mechanisms will be developed to permit layers to respond to negotiated QoS constraints (propagated through the control interface) and environmental conditions. Special emphasis will be placed on supporting real-time, reliability, and security constraints and on innovative operating system designs that efficiently integrate communications and computation to satisfy application-specific requirements. Distributed object technologies based on COBRA with QoS extensions will also be developed.
- **Adaptive Resource Manager:** A global operating system must have the ability to monitor and collect information on the status of resources, maintain a consistent distributed view of that status, profile applications to permit mapping them onto the most appropriate available resources, and dynamically allocate and schedule resources to meet end-to-end QoS constraints. This task will develop algorithms and resource management technologies to permit the dynamic discovery of resources; dynamic near-optimal allocation of heterogeneous resources to applications, balancing each application's end-to-end real-time quality-of-service constraints against overall efficiency and fairness criteria; and rapid dynamic reconfiguration in response to failures, workload variations, information warfare attacks, or crisis response demands.
- **Integration, Validation, and Demonstration:** This task will coordinate the development of component technologies under subtasks 2.1-2.3 through the definition of standard interfaces to ensure interoperability; construction of testbeds for the comparative evaluation of similar technologies; construction and evaluation for major subsystems; construction and distribution of a series of complete

reference implementations and demonstration of key applications. Under separate funding, these capabilities will be transitioned to DoD testbeds for demonstration on command and control applications.

3. Network Management - Managing networks the size and complexity of those entailed by the goals of the NGI will require a sharp acceleration away from current ad hoc and labor intensive methods, and the network engineering tasks described here will move the networking community towards accurately planned and self-configuring systems. The enabling components fall into three categories: planning tools, advanced monitoring and discovery devices and monitoring software, and data presentation tools.

- **Planning Tools:** The planning tool task will develop software for turning specifications of large networks into detailed plans for configuring all devices, protocols, and runtime management software. The specifications will describe the sites, existing capabilities, and new requirements, and the planning tool will use a combination of user interaction and previously used plans to develop a complete and detailed specification. Using network simulation software, the planning tool will validate the plan, noting discrepancies for correction. The planning software will be developed using distributed system techniques, allowing for either central or federated planning.
- **Advanced Monitoring and Discovery Devices and Monitoring Software:** As network speeds increase relative to processor speeds, the ability to do real-time monitoring of traffic decreases. The monitoring is an essential diagnostic tool, and it also permits the network to adjust to traffic conditions and maximize use of its resources. The advanced monitoring task will develop high-speed monitoring devices that work in conjunction with network switches and routers to accumulate detailed traffic statistics and to report them to analysts in a timely fashion. Reporting will be accomplished by developing new monitoring protocol software that adapts to available bandwidth and does not impact overall network performance adversely.
- **Data Processing Tools:** Operators and analysts must have a coherent view of the real-time performance of the NGI, and they must also be able to use time-averaged and historical data for diagnosis and correction of network problems. Advanced techniques for displaying great volumes of data in an understandable fashion will be at the heart of the third network management task. The monitoring and planning and configuration data in the first two tasks will be integrated into a very large screen display which will enable operators to concentrate on data interpretation using a wide variety of visualization techniques.



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Department of Energy Role in NGI

Department of Energy Roles and Responsibilities

The FY 1998 Budget request includes \$35 million within the Office of Energy Research to support DOE's participation in the Next Generation Internet Initiative, a multi-agency effort that includes the Department of Defense, Department of Energy, National Science Foundation, National Aeronautics and Space Administration, and the Department of Commerce.

This initiative is important to DOE because the DOE missions require the interconnection and integration of its unique resources including user facilities, databases, supercomputers, and geographically distributed researchers and scientists located at universities, Federal research institutions, and industry. The DOE Energy Research funded research community consists of over 242 universities and 25 laboratories where DOE has significant research programs in place. The importance to DOE of coupling resources at different sites to solve critical problems is underlined by projects such as the DOE2000 collaboratories, the Accelerated Strategic Computing Initiative (ASCI), the ORNL/Sandia coupled supercomputer experiments, and the High Energy Physics collaboration with the Large Hadron Collider experiment at CERN.

Unfortunately, the current Internet is too unreliable, too primitive, and too low capacity to support these requirements well. DOE and other agencies have been working on technologies in concert with private industry to improve the Internet. This initiative provides the critical mass and leverage to unite this work and bring it to rapid fruition.

The initiative has three goals:

- **Goal 1:** Develop the next generation network fabric and connect universities and Federal research institutions at rates that are 100 to 1000 times faster than today's Internet: These networks will connect at least 100 Federal research institutions at speeds that are 100 times faster than today's Internet, and a smaller number of Federal research institutions at speeds that are 1,000 times faster than today's Internet.
- **Goal 2:** Advanced Network Services Technologies
- **Goal 3:** To Demonstrate New Applications

DOE's Role

Goal 1: Networks (\$25 million). Because of its successful history with ESnet, DOE has been assigned one of the major roles in this goal of the initiative. DOE, in close cooperation with DARPA, NASA, and NSF, will participate in the network testbeds interconnecting universities, Federal research institutions, and other related institutions. In achieving goal 1, DOE expects to devote a substantial part of these funds, jointly with NSF, to ensure major university participation in the network testbeds.

ESnet, in concert with other parts of the Internet, has already become a critical component in the conduct of scientific research and other aspects of the DOE mission, permitting scientists to work together in ways that

were not imagined even a few years ago. For example, fusion scientists from Oak Ridge (ORNL), Princeton (PPPL), Livermore (LLNL), and General Atomics routinely use ESnet to design and carry out experiments at the DIII-A fusion research facility in San Diego. Faculty and students from the University of Wisconsin use ESnet to conduct experiments at Berkeley Lab's Advanced Light Source. These are examples of early implementation of what are called collaboratories (collaborative laboratories). This new era of technology will be further developed and deployed as part of the department's DOE2000 Collaboratory Initiative.

Outside of the NGI initiative, the DOE FY 1998 request for large scale networking includes \$13.79 for ESnet operations. ESnet provides a leading edge network infrastructure for the high performance computational research activities and funds advanced networking research activities. ESnet, using laboratory-industry partnerships, provides advanced services through the early acquisition and testing of commercially supplied communications and network services.

Goal 2: Technologies (\$6 Million). DOE has a significant role in fulfilling this goal of the initiative in partnership with DARPA and other agencies. DOE-sponsored research will focus on important issues such as network performance measurement, network management and quality of service, and network security. DOE has already funded and managed research in advanced network technologies that have produced widely used advances such as tools for Internet video applications and high speed network hardware. These advances played a critical role in the recent interagency Gigabit testbed program.

Goal 3: Applications (\$4 million). DOE has already embarked on a number of applications which will require the facilities of the Next Generation Internet to be fully successful. The National Energy Research Scientific Computing Center (NERSC) is an example of how DOE is already pushing the edges of "distance research" and high-performance computing to advance agency missions. Also, applications such as the Accelerated Strategic Computing Initiative (ASCI), combustion climate modeling, fusion theory, high energy physics, and collaboratory projects in the DOE2000 initiative have already demonstrated the requirement for very fast communications across multiple sites. The challenge for DOE's NGI applications is to scale these initial tests to broader communities and larger numbers of sites by cofunding the development of tools and interfaces that enable users to link their applications to the NGI testbeds.

The following DOE Base Program activities, outside of the NGI initiative, support the NGI applications Goal 3:

- National Energy Research Scientific Computing Center, which provides high performance computing resources to over 4000 users working on about 700 projects at universities, National Laboratories, and industry.
- Advanced Computational Testing and Simulation Research effort supports research at 10 DOE laboratories and over 30 universities in the development of theory, algorithms, and tools for enabling the solution of large scientific and engineering problems. It also supports over 50 doctoral students in computational science and engineering at selected universities. Participating fellows also spend at least one summer at a DOE laboratory in the area of their dissertation.
- Grand Challenge Applications which includes activities in Computational Chemistry, Computational Structural Biology, Mathematical Combustion Modeling, Quantum Chromodynamics Calculations, Oil Reservoir Modeling, Numerical Tokamak Project, Global Climate Modeling, and First Principles Simulation of Material Properties. These activities are crucial to energy issues and are co-funded by other DOE programs and by industrial partners and other agencies.
- DOE2000 develops an integrated set of algorithms, software tools, and infrastructure to enable computer simulation to be used in place of experiments when real experiments are too dangerous, expensive, inaccessible, or politically infeasible.
- High Performance Computing Resources Providers which provide the critical resources for enabling the Grand Challenge applications. They integrate the early high performance computing systems into a prototype heterogeneous computing configuration and make them available to the research community.



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National Aeronautics and Space Administration Role in the NGI

The FY 1998 Budget request includes \$10 million within the HPCC Program to support NASA's participation in the Next Generation Internet initiative, a multi-agency effort that includes the Department of Defense, National Aeronautics and Space Administration, Department of Energy, National Science Foundation, and the Department of Commerce. The President has committed to a three year funding period at \$100M per year.

This initiative is important to NASA because the NASA missions require the interconnection and integration of its unique resources including user facilities, databases, supercomputers, and geographically distributed researchers and scientists located at universities, Federal research institutions, and industry. The NASA-funded research and engineering community consists of over 180 universities, 30 industry partners and 5 science and research centers where NASA has significant research programs in place. The importance to NASA of coupling resources at different sites to solve critical problems is underlined by projects such as the Computational Aerosciences (CAS), Earth and Space Sciences (ESS), Advanced Design Testbeds and Experimentation (ADTE), Aerospace Telemedicine, Aviation Safety, networked supercomputing and virtual aerospace environments for NASA full motion simulator facilities, collaborative communications for Astrophysics and advanced science investigations for Mission to Planet Earth.

Unfortunately, the current Internet is too unreliable, too primitive, and too low capacity to support these requirements well. NASA and other agencies have been working on technologies in concert with private industry to improve the Internet. This initiative provides the critical mass and leverage to unite this work and bring it to rapid fruition.

The initiative has three goals:

- **Goal 1:** Develop the next generation network fabric and connect universities and Federal research institutions at rates that are 100 - 1000 times faster than today's Internet: These networks will connect at least 100 Federal research institutions at speeds that are 100 times faster than today's Internet, and a smaller number of Federal research institutions at speeds that are 1,000 times faster than today's Internet.
- **Goal 2:** Advanced Network Services Technologies- Invest in research and development that will enhance the capabilities of the Internet, such as real-time services.
- **Goal 3:** Demonstrate new applications that support important national goals and missions such as scientific research, national security, distance education, environmental monitoring and health care.

NASA's role:

Goal 1: (\$3 million) Because of its successful history with the NASA Science Internet (NSI) and NASA's Research and Education Network (NREN), NASA has been assigned a major role in this goal of the initiative. NASA, in close cooperation with DARPA, DOE, and NSF will establish the two network testbeds interconnecting universities and Federal research institutions. NREN, in concert with other parts of the Internet, has already become a critical component in the conduct of scientific research and other aspects of the NASA mission, permitting scientists to work together in ways that were not imagined even a few years ago. The

ultimate structure of the NREN gigabit network will evolve as national gigabits research efforts are completed. Fiber-optic trunks now being installed by communications carriers will become increasingly important. Achieving seamless interoperability across hybrid networking architectures and diverse systems will contribute to NASA missions and the nation's communications industry. Among the features to be packed into NREN under the NGI program will be new switching systems, network protocols, high-speed interconnections to workstations and supercomputers as well as new forms of interconnection with the interagency Internet. The gigabit research effort is to support such advanced capabilities as remote interactive graphics, nationwide digital libraries, and network-based high-definition displays for science, manufacturing and education. Managing the dynamics of these activities will be a major challenge, but the payoff for success will be enormous in terms of National Information Infrastructure capabilities, research productivity, and new commercial products and services.

Goal 2: Technologies (\$2 Million) NASA has a significant role in fulfilling this goal of the initiative in partnership with DARPA and other agencies. NASA will deploy an appropriate suite of advanced networking services to enable high performance applications. NASA sponsored research will focus on important issues such as network performance measurement, network interoperability and quality of service, and network security. NASA will fund and managed research in advanced network technologies that are richer in features, higher in performance, and deliverable at a reasonable cost. For example, they will enable real-time networking, group collaborations and a seamless interface for space-to-ground communications.

Goal 3: Applications (\$5 Million) NASA has already embarked on a number of applications which will require the facilities of the Next Generation Internet to be fully successful. Earth and space scientists need to develop new ways of working in small and large teams to combine data and produce models meaningful for human interpretation and discussion. Scientists in these disciplines are located all over the US and the world, as earth resources and environmental phenomena and the space environment are of worldwide interest. US scientists are developing sophisticated computer-based tools, supercomputer models, and massive archives of space and related data. They need to develop new ways of connecting themselves and their facilities together over high performance networking, in ways that will change the process by which they do science. For example, distributed image spreadsheets can be created in which several images and models driven in realtime from different locations over the network can be brought to a desktop supercomputer workstation, then quickly combined and manipulated to produce meaningful scientific products. These products can then be published in near real-time to multimedia videoconferences of scientists working in the specialized discipline, resulting in both orders of magnitude more science productivity as well as dramatic reductions in time needed to produce meaningful results for educators, policy makers, and other scientists. This new era of technology will be further developed and deployed as part of NASA's High Performance Computing and Communications Program in partnership with the Mission to Planet Earth Program.



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National Institute of Standards and Technology Role in the NGI

The FY98 Budget request includes \$5.46 million to support the participation of NIST in the Next Generation Internet. Approximately \$2M of NIST's R&D projects described under number 2 (below) contribute to Goal 2 of the Initiative, which is to promote experimentation with the next generation of networking technologies

Approximately \$3M of NIST's R&D projects described under numbers 1 and 3 below contribute to Goal 3 of the Initiative, which is to demonstrate new applications that meet important national goals and missions.

NIST's contributions to the goals of the NGI Initiative of the CCIC's Large Scale Networking (LSN) focus area can be summarized as:

NIST:

- Develops test methods and technical solutions for technologies to protect systems, networks, and data in advanced Internet applications such as electronic commerce, health care, and research and development collaboration.

Activities in support of secure systems and networks include development of criteria, tests and test methods for Internet/internetwork security, cryptographic technology, advanced authentication technology, and public key and key management infrastructure.

- Provides test methods, reference implementations, and testbeds which support experimentation with and interoperability of next-generation networking technologies.

Activities in support of experimentation with next-generation networking technologies include development of a reference implementation and a remotely-accessible interoperability testbed for IPv6, development of an Integrated Services Packet Switched network testbed and instrumentation tools for Quality of Service in IP-based networks, protocol simulation and analysis for advanced ATM networks, research in high-speed residential access, and tests and measurement methods for evaluating next-generation, intelligent collaborative tools.

- Demonstrates the principles and implementation of distributed and virtual manufacturing technologies which can dramatically reduce the time required to develop new products.

Through the National Advanced Manufacturing Testbed, the Manufacturing Engineering Laboratory and its industrial, government and academic partners develop, integrate, operate, test, benchmark, and refine advanced manufacturing measurements and standards and demonstrate approaches to distributed design, engineering, and manufacturing operations. This effort leverages resources from several manufacturing facilities, tying together NIST capabilities with those of its partners.



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National Science Foundation Role in NGI

The FY98 Budget request includes \$10 million to support the participation of NSF in the Next Generation Internet initiative. This initiative is recommended for funding at \$100 million per year for three years across the Department of Defense, Department of Energy, National Science Foundation, National Aeronautics and Space Administration, and the National Institute of Standards and Technology. It will leverage a much greater investment, however, in these agencies, other agencies, universities, and industry in a coordinated partnership.

NSF funds research in science, engineering, and education through a system of grants to universities and partnerships with other agencies. The original NSFNET, an NSF program to interconnect these universities with a system of data networks, has had a revolutionary impact on the conduct of research, greatly improving productivity and opening whole new fields of study. The Internet is now a core tool of the research community, which now operates in project teams in multiple locations as required for best results. As the Internet becomes a crowded commercial success, however, there is need once again to improve the network support for research, not just in capacity, but in basic functionality. Newly envisioned applications that link humans with video, voice, and graphics to each other as well as to information and instruments around the world promise to bring a second revolution in productivity for research, pointing to very significant social and economic benefits. The network technologies proved along the way will be adapted rapidly by the private sector to improve the commercial Internet. This requires, however, that we first develop a Next Generation Internet with corresponding higher capabilities.

NSF funding in NGI will be used, for the most part, to greatly accelerate the ongoing development and implementation of a national-scale high-performance network testbed to address the needs of the university research community.

NGI Goals

- **Goal 1:** Develop the next generation network fabric and connect universities and Federal research institutions at rates that are 100 - 1000 times faster than today's Internet: These networks will connect at least 100 Federal research institutions at speeds that are 100 times faster than today's Internet, and a smaller number of Federal research institutions at speeds that are 1,000 times faster than today's Internet.
- **Goal 2:** Technologies to support advanced network services
- **Goal 3:** Demonstrate breakthrough applications that use high-performance networking.

NSF's Role

Goal 1: Networks (\$7 million) Substantially accelerate NSF's program to interconnect additional research universities and centers through the vBNS, a high-performance testbed network, leveraging university funds to upgrade campus and related networks. Work closely with other agencies to interconnect research networks across the entire research community to achieve maximum benefit and leverage. This funding will complement some \$33 million in base funds allocated to this effort, accelerating the new connections by years to meet NGI goals.

Goal 2: Technologies (\$2 million) Support the development of new software systems to enable the seamless convergence of computing and communications. Study basic technologies of future networking. This funding will complement some \$13 million in base funds allocated to such research.

Goal 3: Applications (\$1 million) Increase funding for the development of core applications such as voice and video over the net. Leverage some \$14 million in base funds allocated to research in grand challenges, digital libraries, and new core applications, as well as the much larger collective efforts of faculty and staff at the connected universities.



Send Comments to
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